ELEMENTAL COMPOSITION OF THE CORN PLANT[1]

By W. L. LATSHAW, *Analytical Chemist, Department of Chemistry,* and E. C. MILLER, *Plant Physiologist, Department of Botany, Kansas Agricultural Experiment Station*

INTRODUCTION

Our knowledge concerning the elemental composition of many of the more common agricultural plants is rather limited and fragmentary. The data on this subject have been obtained frequently from material that has been collected under no stated conditions and the earlier determinations are now open to criticism on account of the questionable accuracy of the methods of analysis employed. An accurate elemental analysis of a few mature plants of a given crop grown under well-defined conditions of soil and climate should furnish data from which the amount of the various elements removed from the soil by the crop could be fairly accurately estimated. For this reason it was thought advisable, in some of the experimental work with corn at the Kansas Agricultural Experiment Station, to make an elemental analysis of the plant. With this in view material was collected from mature Pride of Saline corn plants grown in the field at Manhattan, Kans., during the summer of 1920.

CULTURAL METHODS

The plants used in this experiment were grown on plots that had been continuously cropped to corn for about 10 years. The soil was a fertile sandy loam and showed little difference in texture in the first 4 feet. The ground was plowed to a depth of 6 inches in the late fall and received no other cultivation until the following spring, when it was worked into good condition just previous to planting. The seed was surface planted on May 12 in rows 42 inches apart, and after the plants had reached a height of about 3 inches, they were thinned in the row to a distance of 2 feet between each plant. The plot was kept free from weeds by hoeing, and with the exception of a shallow cultivation on June 3 the soil was not stirred during the growing season. Since no visible signs of wilting were evident at any time during the summer, it is assumed that the supply of water in the soil was adequate. A summary of the general climatic conditions prevailing during the growing season is given in Table I.

[1] Received for publication Mar. 1, 1924. Published with the approval of the Director as paper No. 219, Department of Botany, and paper No. 106, Department of Chemistry, Kansas Agricultural Experiment Station.

Journal of Agricultural Research,
Washington, D. C.

Vol. XXVII, No. 11
Mar. 15, 1924
Key No. Kans.-42

85606—24——4

TABLE I.—*Summary of the climatic conditions at Manhattan, Kans., for the growing season of 1920*

Month.	Days (inclusive).	Air temperature (° F.).					Precipitation.	Evaporation from free water surface.
		Average of—			Maximum.	Minimum.		
		Mean.	Maximum.	Minimum.				
							Inches.	*Inches.*
May	1–5	61	71	51	74	42	.....	0.568
Do	6–10	61	73	50	83	46	0.64	.783
Do	11–15	59	68	51	81	40	.25	.713
Do	16–20	61	72	51	85	45	.04	.591
Do	21–25	70	79	61	88	47	.48	.801
Do	25–31	69	79	58	92	54	.17	.810
June	1–5	65	77	54	82	40	.34	1.077
Do	6–10	78	90	67	98	58	.....	1.405
Do	11–15	84	96	73	99	72	.....	1.983
Do	16–20	68	78	59	91	55	.04	1.253
Do	21–25	70	87	55	90	47	.76	1.418
Do	26–30	84	79	61	98	69	.82	1.776
July	1–5	83	96	70	100	61	.02	1.339
Do	6–10	71	85	57	89	54	.15	1.422
Do	11–15	77	90	65	95	55	1.02	1.520
Do	16–20	79	93	65	97	61	.....	1.290
Do	21–25	82	97	67	105	63	.....	1.725
Do	26–31	72	85	59	94	51	3.64	1.143
August	1–5	74	86	63	90	58	.....	1.128
Do	6–10	79	94	61	96	57	.....	1.080
Do	11–15	70	84	56	90	47	.12	1.232
Do	16–20	71	87	53	91	48	5.18	.857
Do	21–25	68	79	58	85	51	.....	1.172
Do	26–31	73	84	62	92	56	.87	1.306

COLLECTION AND PREPARATION OF MATERIAL

STEMS, LEAVES, AND GRAIN

Five plants were selected and harvested on September 2, when the grains were in the late-dough stage and were well glazed and dented (Pl. 1, A). At this stage of development it was thought that the plants had removed from the soil most of the minerals of which they were capable, although there would probably be some slight rearrangement of materials in the various plant parts before full maturity. Furthermore, at this stage the leaves were all attached to the plants (Pl. 1, B) and green, so that little or no material had been lost from them by leaching. It is worthy of note that a gentle rain fell during the night of September 1, so that the leaves and stems were especially free from any adhering dirt when they were harvested. The plants were cut off at the surface of the ground and their green weight at once determined. A general description of each of the five plants at the time of harvesting is given in Table II.

As soon as the green weight of each plant was determined, the stem, leaves, and grain were separated, ground or cut into convenient pieces, and placed in a hot air drying oven at 105° C. for 24 hours. The material was then transferred to glass jars and sealed until it was ready to be

pulverized for chemical analysis. In the preparation of material the husks were placed with the leaves and the tassel with the stem. The cobs of the five plants were ground together and the analysis made of this mixture, so that the variation in the composition of these organs was not determined.

TABLE II.—*General description of the five corn plants at the time of harvesting*

Plant No.	Total green weight.	Dry weight of—					Percentage of moisture in plant.	Height of plant.	Length of ear.	Number of leaves.
		Entire plant, excluding the roots.	Stems and tassel.	Leaves[a] and husks.	Grain.	Cob.				
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*		*Inches.*	*Inches.*	
1.....	2,540	776.3	154.3	209.4	320.0	92.6	69.4	102	12	15
2.....	2,923	791.1	191.2	252.4	272.2	75.3	72.9	96	13	16
3.....	2,277	659.5	161.0	195.8	232.0	70.7	71.0	101	12	14
4.....	2,716	745.8	233.0	235.5	212.0	65.3	72.5	108	11	14
5.....	3,095	899.3	263.5	279.7	268.8	87.3	70.9	120	13	17
Average.	2,710	774.4	200.6	234.6	261.0	78.2	71.4	105	12	15

[a] Including sheaths.

ROOTS

It is practically impossible to collect all of the roots of a corn plant grown under crop conditions in the field since one is unable to distinguish or separate the finer roots that are interwoven with those of the adjacent plants. In order to obtain the entire root system, plants of the same variety of corn as that grown in the field were grown singly in soil in large galvanized iron cans. These cans contained a sufficient volume of soil to grow plants to maturity that in appearance were the equal in every regard of those growing under the conditions of the surrounding field. The methods used in growing plants in such containers have been previously described by Miller (*8*, *9*)[2] and will not be discussed here. When the plants in the cans had reached maturity, the aerial parts were harvested and discarded and the roots collected in the following manner: The soil contained in the can was emptied upon a cleared space and the larger roots removed by careful sorting. The soil with the smaller roots was then placed in vessels and covered with a large excess of water which was stirred vigorously until the soil had disintegrated into fine particles. As soon as the stirring ceased, the soil settled to the bottom of the vessels while the remnants of roots floated to the surface and were removed by skimming with a fine sieve. The process was repeated several times until all the roots had been separated from the soil. The roots thus obtained were washed carefully until, in so far as could be seen, they were free from all soil particles, dried in a hot-air oven at 105° C. for 24 hours, and stored in sealed jars until chemical analyses could be made. A representative root system of one of the five obtained after this manner is shown in Plate 1, C.

[2] Reference is made by number (italic) to "Literature cited," p. 859.

CHEMICAL METHODS

The chemical determinations of the various elements with the exception of sulphur and phosphorus were made, in general, according to the methods for the analysis of plant material recommended by the Association of Official Agricultural Chemists. The sulphur and phosphorus were determined after the following method described by Latshaw (7). One to two grams of the sample, or a sufficient amount to give a precipitate of not less than 30 mgm. of barium sulphate, were weighed into a 250 cc. low form Pyrex beaker. To this were added 7.5 cc. of a magnesium nitrate solution,[3] care being taken that all the material was brought in contact with the solution and heated on an electric hot plate (180° C.) until no further action took place. The beaker was transferred while hot to an electric muffle and allowed to remain at low heat (muffle not showing any red) until the charge was thoroughly oxidized and no black particles remained. If necessary, the charge was broken up and again returned to the muffle. The beaker was removed from the muffle and allowed to cool. Water was added, then hydrochloric acid in excess, the solution brought to a boil, filtered and washed thoroughly. This solution was then diluted to 200 cc., heated to boiling, and a 10 per cent barium chlorid solution added in small quantities until no further precipitate was formed. The boiling was continued for five minutes, after which the liquid was allowed to stand for five hours or longer in a warm place. The liquid was then decanted on an ashless filter or a tared Gooch crucible previously heated, the precipitate treated with 15 to 20 cc. of boiling water, transferred to the filter and washed free of chlorids with boiling water. The precipitate was ignited and weighed as barium sulphate. The filtrate obtained in the sulphur determination was evaporated to 75 cc. and the phosphorus determined by the method recommended by the Association of Official Agricultural Chemists.

The figures in the various tables representing the amounts of oxygen include the oxygen obtained by the usual procedure in organic analysis plus the oxygen that was a part of the various mineral elements of the ash when they were converted to their oxids. The figures thus represent the oxygen of both organic and inorganic combination.

The determinations were all made in duplicate or triplicate and whenever any striking differences appeared in the analysis of the individual plants a careful redetermination was made to verify the results. Any marked differences recorded in the composition of the same organ of the different plants are due to individual variations and not to discrepancies in the chemical methods used.

DISCUSSION OF EXPERIMENTAL DATA

In order to determine the variation in the composition of the different plants and their organs a separate analysis was made of the leaves, stem, and grain of each of the five plants. A separate analysis was also made of each of the five root systems. Determinations were made for carbon, oxygen, hydrogen, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, silicon, aluminum, chlorin, and manganese. The amount of each of the elements that compose the leaves, stem, and grain of each of the five plants is expressed in percentage of dry weight and in the actual amount, in grams, in Table III.

[3] Made by dissolving 320 gm. of calcined magnesia in nitric acid, avoiding an excess of the latter. Calcined magnesia is then added slightly in excess, the solution boiled, filtered from the excess of magnesia, iron aluminia, etc., and diluted to two liters.

In Table IV the composition of the five root systems is expressed in the same manner. The data in Table III shows a striking uniformity in the elemental composition, expressed in percentage of dry weight, of the leaves, stem and grain of each of the five plants analyzed. The only marked exceptions in this regard were the rather wide variations in the percentages of oxygen and chlorin. This was true, however, only of the stems and leaves since the percentages of these two elements in the grain were very uniform. The percentages of several of the mineral elements in the five root systems showed considerable variation which may have been due, in part, to the unequal distribution of minute particles of soil adhering to or embedded in the exterior tissue of the roots.

Although the percentage elemental composition is uniform in a like organ of the different plants, the actual amount of a given element expressed in grams varies considerably, as shown in the latter part of Table III. This is due to the fact that plants which are grown under the same conditions in the field and which seem to be uniform in size and general appearance show marked variations in dry weight and in the distribution of this matter in the various organs of the plants.

DISTRIBUTION OF THE ELEMENTS IN THE ORGANS OF THE PLANT

The total dry weight of the leaves, stem, grain and cobs of each of the five corn plants analyzed was 776.3, 791.1, 659.5, 745.8 and 899.3 gm., respectively. The average amount of dry matter in the aerial parts of the plants was thus 774.4 gm., of which 30.2 per cent was in the leaves, 26 per cent in the stem, 33.7 per cent in the grain and 10.1 per cent in the cob. This proportion of dry matter in the various organs corresponds closely to the observations of Smith (*11*) on corn grown in Michigan. He found that 22 per cent of the dry matter of the plant above ground was in the leaves, 32 per cent in the stalks and 46 per cent in the ears. Table IV shows that the dry weight of each of the five root systems isolated was, respectively, 59.5, 62.4, 60.7, 53.9, and 66.0 gm., with an average weight of 60.5 gm. The weight of the dry matter of the roots was thus 7.81 per cent of the dry weight of the leaves, stem and ear. The weight of the roots obtained in this experiment is in accord with unpublished data that have been obtained in numerous experiments with the corn plant at the Kansas Agricultural Experiment Station. These data show that the dry weight of the roots of a mature Freed White Dent, Kansas Sunflower, Reid Yellow Dent or Pride of Saline corn plant was between 7 and 8 per cent of the dry weight of the portion of the plant above ground.

The values for the weight of the dry matter of the roots of corn are much higher than those given by Hornberger (*3*) and Schweitzer (*10*). Their results show that the dry weight of the roots of mature corn plants grown in the field did not exceed 3 per cent of the dry weight of the plants. They state, however, that the methods used by them to isolate the root systems were unsatisfactory since there was no degree of certainty that they had obtained all the roots.

The average percentage composition of the different organs of the five plants is shown in the first half of Table V. The average weight in grams of the elements that compose, respectively, the stem, leaves, grain, cob, and roots is shown in the last half of Table V. These values expressed in grams were obtained by multiplying the average weight of the organs by their average percentage composition. The total weight of each of the elements that make up the mature plant is expressed graphically in Figure 1.

TABLE III.—*Elemental composition of the leaves, stems, cobs, and grain of five Pride of Saline corn plants grown in the field at Manhattan, Kans., in 1920*

Plant No.	Organ.	Dry weight.	ELEMENTS. Carbon.	Oxygen.	Hydrogen.	Nitrogen.	Phosphorus.	Potassium.	Calcium.	Magnesium.	Sulphur.	Iron.	Silicon.	Aluminum.	Chlorin.	Manganese.
			PERCENTAGE OF THE ELEMENTS, DRY BASIS.													
1	Leaves		41.18	45.28	5.75	1.16	0.169	1.57	0.56	0.25	0.25	0.070	2.44	0.075	0.34	0.031
2	do		40.85	44.49	6.20	1.40	.202	1.57	.38	.23	.23	.073	2.20	.086	.43	.023
3	do		42.25	43.35	5.77	1.43	.225	1.32	.46	.20	.23	.081	2.69	.074	.073	.036
4	do		40.85	44.24	5.82	1.21	.186	1.54	.49	.17	.24	.058	2.57	.071	.154	.044
5	do		41.22	41.95	5.78	1.32	.256	1.38	.47	.20	.23	.070	3.05	.063	.115	.025
1	Stem		43.96	43.91	5.66	.88	.073	1.64	.14	.14	.15	.052	.43	.016	.40	.016
2	do		44.08	42.90	5.83	.94	.093	1.09	.19	.18	.13	.040	.30	.014	.40	.010
3	do		46.35	42.50	6.00	.50	.072	1.12	.14	.12	.16	.046	.41	.012	.13	.023
4	do		44.35	45.00	5.93	.85	.081	1.13	.20	.14	.17	.046	.49	.012	.072	.017
5	do		43.80	45.20	6.08	1.02	.124	1.16	.20	.21	.17	.074	.47	.012	.12	.018
1	Grain		45.25	45.05	7.01	2.14	.31	.37	.035	.20	.12	.049	.018	.020	.026	.027
2	do		44.48	45.42	7.02	2.14	.33	.51	.028	.20	.18	.030	.014	.036	.031	.044
3	do		44.75	45.31	6.93	2.22	.33	.43	.023	.19	.12	.028	.021	.033	.031	.050
4	do		45.10	44.67	6.94	2.24	.40	.45	.021	.19	.14	.055	.016	.014	.031	.043
5	do		44.00	46.04	6.92	2.03	.34	.34	.019	.21	.12	.055	.011	.013	.046	.023
	Cobs		45.75	45.89	6.36	1.38	.094	.46	.022	.11	.021	.025	.133	.052	.12	.031
			TOTAL WEIGHT OF THE ELEMENTS IN GRAMS.													
1	Leaves	209.4	86.23	94.81	12.04	2.42	0.353	3.28	1.17	0.523	0.523	0.146	5.10	0.157	0.711	0.065
2	do	252.5	103.10	112.29	15.64	3.53	.510	3.96	.96	.581	.581	.184	5.55	.217	1.085	.058
3	do	195.8	82.72	84.87	11.29	2.79	.440	2.58	.90	.391	.450	.158	5.27	.144	.142	.070
4	do	235.5	96.20	104.18	13.71	2.84	.438	3.62	1.15	.400	.565	.136	6.05	.167	.362	.104
5	do	279.7	115.29	117.33	16.16	3.69	.716	3.86	1.31	.559	.643	.195	8.53	.176	.321	.069

1	Stems	154.3	67.83	67.75	8.73	1.36	.112	2.53	.21	.210	.231	.080	.66	.024	.617	.024
2	.....do	191.2	84.28	82.02	11.14	1.79	.177	2.08	.36	.344	.248	.076	.57	.026	.760	.019
3	.....do	161.0	74.62	68.42	9.66	.81	.115	1.80	.23	.193	.257	.074	.66	.019	.209	.037
4	.....do	233.0	103.33	104.85	13.81	1.98	.188	2.63	.46	.326	.396	.107	1.14	.027	.167	.039
5	.....do	263.5	115.40	119.10	16.02	2.68	.326	3.05	.52	.553	.447	.194	1.23	.031	.316	.047
1	Grain	320.0	144.80	144.16	23.43	6.84	.990	1.18	.112	.640	.384	.156	.057	.064	.083	.086
2	.....do	272.2	121.07	123.63	19.10	5.82	.890	1.38	.076	.544	.489	.082	.038	.098	.084	.119
3	.....do	232.0	103.82	105.11	16.07	5.15	.760	1.00	.053	.440	.278	.065	.049	.076	.072	.116
4	.....do	212.0	95.61	94.70	14.71	4.74	.850	.96	.045	.406	.299	.117	.034	.029	.066	.092
5	.....do	268.8	118.27	123.75	18.60	5.45	.910	.91	.051	.564	.322	.147	.029	.035	.123	.061
1	Cobs	92.6	42.36	42.49	5.88	1.27	.087	.425	.020	.101	.019	.023	.123	.048	.111	.029
2	.....do	75.3	34.44	34.55	4.78	1.03	.071	.346	.017	.083	.016	.018	.100	.039	.090	.023
3	.....do	70.7	32.34	32.44	4.49	.98	.066	.325	.015	.078	.015	.018	.094	.037	.085	.022
4	.....do	65.3	29.87	29.96	4.15	.90	.061	.30	.014	.072	.014	.016	.086	.034	.078	.020
5	.....do	87.3	39.93	40.06	5.55	1.20	.082	.40	.019	.096	.018	.022	.116	.045	.104	.027

TABLE IV. *Elemental composition of the roots of five Pride of Saline corn plants grown in containers at Manhattan, Kans., in 1920*

Plant.	Dry weight.	ELEMENTS.												
		Carbon.	Oxygen.	Hydrogen.	Nitrogen.	Phosphorus.	Potassium.	Calcium.	Magnesium.	Sulphur.	Iron.	Silicon.	Aluminum.	Chlorin.	Manganese.
		PERCENTAGE OF THE ELEMENTS, DRY BASIS.													
A		42.50	46.14	5.93	1.27	0.141	0.27	0.58	0.18	0.28	0.43	6.63	0.89	0.12	0.045
B		43.37	45.80	5.79	1.24	.122	.57	.56	.17	.25	.44	4.89	.94	.09	.088
C		43.35	43.15	6.01	1.27	.121	.56	.64	.18	.23	.45	3.38	.89	.10	.056
D		42.65	42.05	5.56	1.40	.101	.37	.72	.15	.24	.50	4.17	1.15	.12	.089
E		39.70	40.78	5.33	1.16	.113	.65	.56	.16	.23	.76	3.13	1.02	.11	.055
		TOTAL WEIGHT OF THE ELEMENTS IN GRAMS.													
A	59.5	25.28	27.45	3.53	0.75	0.083	0.160	0.345	0.107	0.166	0.255	3.94	0.529	0.071	0.027
B	62.4	27.06	28.57	3.61	.77	.076	.355	.349	.106	.156	.274	3.05	.586	.056	.055
C	60.7	26.31	26.19	3.64	.77	.073	.339	.388	.109	.139	.273	2.05	.540	.061	.034
D	53.9	22.98	22.66	3.00	.75	.054	.199	.388	.081	.129	.269	2.24	.619	.064	.048
E	66.0	26.20	26.91	3.51	.76	.074	.429	.369	.105	.151	.501	2.06	.673	.073	.036

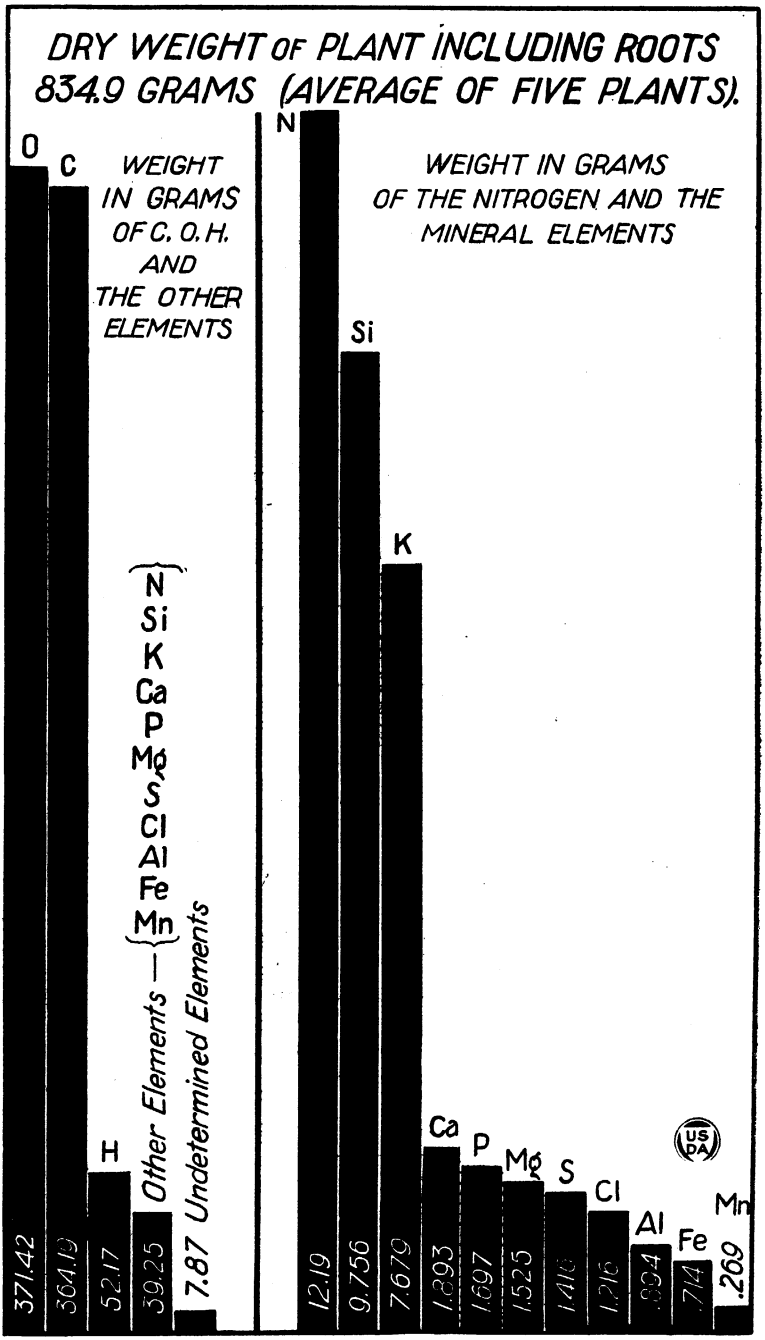


FIG. 1.—Relative amount of the elements that composed the dry matter of Pride of Saline corn grown at Manhattan, Kans., in 1920.

TABLE V.—*Average amount of the elements in the leaves, stems, cobs, grain, and roots of five Pride of Saline corn plants grown at Manhattan, Kans., in 1920*

Organ.	Dry weight.	ELEMENTS.													
		Carbon.	Oxygen.	Hydrogen.	Nitrogen.	Phosphorus.	Potassium.	Calcium.	Magnesium.	Sulphur.	Iron.	Silicon.	Aluminum.	Chlorin.	Manganese.
		PERCENTAGE OF THE ELEMENTS, DRY BASIS.													
Leaves	.....	41.27	43.86	5.86	1.30	0.207	1.48	0.47	0.21	0.24	0.070	2.59	0.074	0.222	0.043
Stems	.....	44.51	43.90	5.90	.84	.089	1.23	.17	.16	.16	.052	.42	.013	.224	.017
Grain	.....	44.72	45.30	6.96	2.15	.34	.42	.025	.20	.14	.043	.016	.023	.033	.037
Roots	.....	42.31	43.58	5.72	1.27	.120	.48	.61	.17	.25	.52	4.44	.98	.11	.066
Cobs	.....	45.75	45.89	6.36	1.38	.094	.46	.022	.11	.021	.025	1.33	.052	.12	.031
		TOTAL WEIGHT OF THE ELEMENTS IN GRAMS.													
Leaves	234.60	96.82	102.89	13.74	3.05	0.486	3.47	1.101	0.493	0.563	0.164	6.08	0.174	0.521	0.075
Stems	200.60	89.29	88.06	11.83	1.68	.178	2.47	.341	.321	.321	.104	.84	.026	.449	.034
Grain	261.00	116.72	118.23	18.17	5.61	.887	1.09	.065	.522	.365	.112	.042	.060	.086	.096
Roots	60.50	25.59	26.36	3.46	.77	.072	.290	.369	.103	.151	.315	2.69	.593	.066	.040
Cobs	78.20	35.77	35.88	4.97	1.08	.074	.359	.017	.086	.016	.019	.104	.041	.094	.024
Average total weight	834.90	364.19	371.42	52.17	12.19	1.697	7.679	1.893	1.525	1.416	.714	9.756	.894	1.216	.269

Taking the average dry weight of the aerial parts of the plants as 774.4 gm. and the average dry weight of the roots as 60.5 gm., the average total dry weight of a Pride of Saline corn plant grown under the conditions of this experiment amounted to 834.9 gm. Of this total amount of dry matter 28.10 per cent was in the leaves, 24.02 per cent in the stem, 31.26 per cent in the grain, 9.37 per cent in the cob and 7.25 per cent in the roots. Of this total dry weight of the corn plant, carbon composed 43.62 per cent, oxygen 44.48 per cent, hydrogen 6.24 per cent, nitrogen 1.46 per cent, phosphorus 0.204 per cent, potassium 0.919 per cent, calcium 0.226 per cent, magnesium 0.182 per cent, sulphur 0.169 per cent, iron 0.085 per cent, silicon 1.17 per cent, aluminum 0.107 per cent, chlorin 0.145 per cent and manganese 0.032 per cent. Approximately 1 per cent of the total dry weight was thus to be accounted for by the undetermined elements of which, no doubt, sodium represented a considerable proportion. Carbon, oxygen and hydrogen made up 94.34 per cent of the dry weight of the plant. Since 1.46 per cent of the dry matter of the plant was due to nitrogen, the mineral elements in the plant represented only slightly more than 4 per cent of its entire dry weight.

The percentage of the various elements that composed the plants in these analyses corresponded closely to the figures given by other investigators. Hornberger (*3*) worked with Badischer Early corn and made chemical analyses of the plants at seven-day periods throughout the growing season. His analyses show that at the time of maturity calcium, potassium, phosphorus, magnesium, sulphur, silicon, iron and nitrogen made up, respectively, 0.51, 1.19, 0.27, 0.42, 0.08, 0.40, 0.05, and 1.54 per cent of the dry weight of the plants. The figures given by Vivian (*12, p. 9–11*) show that carbon, oxygen and hydrogen made up 92.7 per cent of the dry weight of the corn plant which was ready to be cut for the shock. His results for the percentages of the various mineral elements were practically the same as those reported by Hornberger (*3*). Jones and Huston (*5*) found that potassium, phosphorus and nitrogen made up, respectively, 0.828, 0.193, and 1.17 per cent of the dry weight of the stems, leaves and ears of Riley's Favorite variety of corn when the grain was hard and the plant ready to be cut.

The percentage distribution of the 14 elements in the different parts of the plant is shown in Table VI.

TABLE VI.—*Percentage distribution of the different elements in the leaves, stem, grain, cob, and roots of Pride of Saline corn grown at Manhattan, Kans., in 1920*

Organ.	Elements.													
	Carbon.	Oxygen.	Hydrogen.	Nitrogen.	Phosphorus.	Potassium.	Calcium.	Magnesium.	Sulphur.	Iron.	Silicon.	Aluminum.	Chlorin.	Manganese.
Leaves	26.58	27.70	26.33	25.01	28.63	45.18	58.16	32.32	39.75	22.96	62.32	19.46	42.84	27.88
Stems	24.51	23.70	22.67	13.78	10.48	32.16	18.01	21.04	22.66	14.57	8.61	2.90	36.92	12.64
Grain	32.04	31.83	34.82	46.01	52.26	14.19	3.43	34.22	25.77	15.68	.43	6.71	7.07	35.68
Roots	7.02	7.09	9.52	6.31	4.24	3.76	19.49	6.75	10.66	44.11	27.57	66.33	5.42	14.87
Cobs	9.82	9.66	6.63	8.85	4.36	4.67	.89	5.63	1.12	2.66	1.06	4.58	7.75	8.92

Some of the more important facts shown in this table should be mentioned in the text. The grain and cob contained approximately 55 per cent of the total nitrogen, while 25 per cent of this element occurred in the leaves. The phosphorus was distributed in the same relative

proportion, since 56 per cent of the total phosphorus was in the grain and cob and 29 per cent in the leaves. Approximately 45 per cent of the potassium occurred in the leaves, 32 per cent in the stem and only 19 per cent in the grain and cobs. More than 58 per cent of the calcium was in the leaves, while the stems and roots contained 18 and 19 per cent, respectively. The proportion of calcium in the ear was small and amounted to slightly more than 4 per cent of the total calcium in the plant. In contrast to the calcium, more than 39 per cent of the magnesium occurred in the grain and cob while the proportion of this element in the leaves and stem amounted to 32 and 21 per cent, respectively. The leaves contained 39 per cent of the sulphur, the stem 22 per cent and the grain and cob 26 per cent. Approximately 22 per cent of the iron was found in the leaves, while the stem and grain each contained 15 per cent of this element. The leaves contained the greater part of the silicon, since over 62 per cent of the total amount of this element occurred in them. The ear contained about 1.5 per cent of the silicon and of this amount less than one-half per cent occurred in the grain. The leaves and the stem contained most of the chlorin; 42 per cent of this element occurred in the former and 36 per cent in the latter. Approximately 44 per cent of the manganese occurred in the grain and cob and over 27 per cent in the leaves. The roots contained 6.3 per cent of the nitrogen, 4.2 per cent of the phosphorus, 3.7 per cent of the potassium, 19.5 per cent of the calcium, 6.7 per cent of the magnesium, 10.6 per cent of the sulphur, 44.1 per cent of the iron, 27.5 per cent of the silicon, 66.4 per cent of the aluminum, 5.4 per cent of the chlorin and 14.8 per cent of the manganese. The relatively large proportions of calcium, iron, silicon and aluminum in the roots was due in part, probably, to the minute soil particles that were partially embedded in the surface of the roots and were not removed in the preparation of the material for analyses.

WEIGHT OF THE ELEMENTS REMOVED FROM THE AIR AND SOIL BY AN ACRE CROP OF CORN

Since so many factors can influence the yield and composition of plants, any data concerning the amount of the various elements removed per acre for a given crop are applicable only for the cultural and climatic conditions under which the plants were grown. The recent work of Duley and Miller (*1*) concerning the effect of the supply of nutrients upon the character and composition of the corn plant especially emphasizes this fact. In the experiment herein reported, the plants were grown in 42-inch rows and the plants in the row thinned to a distance of 2 feet. If the stand were perfect under these conditions, there would be 6,270 plants per acre, but in order to allow some leeway 6,200 plants were considered as the stand per acre in estimating the yield of dry matter. The total dry matter produced by 6,200 plants, the average dry weight of which, including the roots, was 834.9 gm., would amount to 11,389 pounds per acre. Since the dry matter of the roots weighed 60.5 gm. per plant, the dry matter produced per acre by them would amount to 825 pounds. The total dry weight of the plants above ground would thus amount to 10,564 pounds per acre. The average dry weight of the lower foot of the stem was determined in order to ascertain the amount of dry matter left on the field by the stubs when the plants were cut at a height of 1 foot from the ground. The average weight of the lower foot of the stem was 28.3 gm. If 6,200 plants were considered as

the stand per acre, the weight of dry matter remaining in the stubs would be 386 pounds. The total weight of dry matter left in the field by the stubs and roots amounted, according to these estimations, to 1,211 pounds per acre, or approximately 10.6 per cent of the total dry matter produced. The total dry matter produced per acre, exclusive of the roots and the stubs 1 foot in height, amounted to 10,178 pounds per acre. This yield of dry matter of the stems, leaves, and ears of the corn plant is considerably higher than that reported by other investigators, but it is difficult to make comparisons since in some cases the variety of corn grown and the height of the stalks when cut at harvesting were not stated. Ladd (*6*) reported a yield of 7,918 pounds of dry matter per acre for the King Phillip variety at the Geneva (N. Y.) Agricultural Experiment Station, but did not mention how much of the stalk was left on the stub. Smith (*11*) obtained a yield of 8,020 pounds of dry matter per acre at the Michigan Experiment Station, but no record of the variety used or the method of harvesting is given. Schweitzer (*10*) at the Missouri Experiment Station considered 6,528 plants to the acre and estimated the total yield of dry matter at 7,892 pounds, but neglected to state the variety of corn used. Jones and Huston (*5*) estimated the yield of dry matter of Riley's Favorite grown at the Indiana Experiment Station at 9,412 pounds when the plants were harvested at the surface of the ground and when 10,000 plants were considered as the stand per acre. Ince (*4*) states that the average yield of dry matter of the ears, stems, and leaves of numerous varieties of corn grown at the North Dakota Experiment Station was 6,130 pounds, but he does not mention how much of the stalk was left on the ground in harvesting.

The estimated weight in pounds of the elements removed per acre from the soil and the air by the entire corn plant and by each of the several organs or parts is shown in Table VII.

TABLE VII.—*Estimated weight in pounds of the elements removed per acre from the air and soil by 6,200 Pride of Saline corn plants grown at Manhattan, Kans., in 1920*

Element.	Weight in pounds of the elements in—									
	Entire plant.	Roots.	Aerial parts.	Stubs 1 foot high.	Roots and stubs 1 foot high.	Grain.	Cobs.	Cobs and grain.	Leaves.	Stems.
Carbon	4,967.55	349.04	4,618.51	171.59	520.63	1,592.06	487.90	2,079.96	1,320.62	1,217.91
Oxygen	5,066.17	359.55	4,706,62	169.27	528.82	1,612.65	489.40	2,102.05	1,493.41	1,201.13
Hydrogen	711.60	47.19	664.41	22.64	69.83	247.83	67.79	315.62	187.41	161.36
Nitrogen	166.27	10.50	155.77	3.22	13.72	76.52	14.73	91.25	41.60	22.91
Phosphorus	23.15	.98	22.17	.04	1.02	12.09	1.01	13.10	6.63	2.42
Potassium	104.74	3.95	100.79	4.74	8.69	14.86	4.89	19.75	47.33	33.69
Calcium	25.82	5.03	20.79	.65	5.68	.89	.23	1.12	15.02	4.65
Magnesium	20.80	1.40	19.40	.61	2.01	7.12	1.17	8.29	6.72	4.37
Sulphur	19.31	2.06	17.25	.61	2.67	4.98	.22	5.20	7.68	4.37
Iron	9.74	4.30	5.44	.19	4.49	1.52	.26	1.78	2.23	1.41
Silicon	133.07	36.70	96.37	1.61	38.31	.42	1.42	1.84	82.93	11.45
Aluminum	12.19	8.09	4.00	.05	8.14	.81	.56	1.37	2.37	.35
Chlorin	16.59	.90	15.69	.84	1.74	1.17	1.28	2.45	7.11	6.12
Manganese	3.67	.55	3.12	.07	.62	1.30	.32	1.62	1.02	.46

These results were obtained by multiplying the weight of each of the different elements in the different organs, as shown in Table V, by 6,200 and reducing the results thus obtained to pounds. The results are self-explanatory and need not be discussed in detail in the text. The figures

in regard to those elements which have been determined by other investigators should be mentioned, however, for the purpose of comparison. The estimated amount of phosphorus, calcium, magnesium, potassium, silicon, and nitrogen removed per acre by the aerial parts of a Pride of Saline corn plant was respectively 22.17, 20.79, 19.40, 100.79, 96.37 and 155.77 pounds. Schweitzer (*10*) considered 6,528 plants of corn per acre and estimated that 83 pounds of phosphorus, 8.9 pounds of calcium, 15 pounds of magnesium, 50 pounds of potassium, 43 pounds of silicon and 135 pounds of nitrogen were removed from the soil by the stems, leaves, and ears of these plants. Hopkins (*2, p. 154*) estimated that a corn crop producing 100 bushels of grain and three tons of stover per acre would remove from the soil 148 pounds of nitrogen, 23 pounds of phosphorus, 71 pounds of potassium, 17 pounds of magnesium, 22.3 pounds of calcium, 5.2 pounds of iron and 6 pounds of sulphur. Jones and Huston (*5*) estimated that the aerial parts of Riley's Favorite corn removed, per acre, 18.3 pounds of phosphorus, 76.2 pounds of potassium and 110.6 pounds of nitrogen. The estimated weight of these elements removed per acre by a crop of Pride of Saline corn grown under the conditions of this experiment was considerably higher than that reported by Schweitzer (*10*) and Jones and Huston (*5*). The greater yield of dry matter per acre as estimated from our experiment would account for a considerable portion of the differences, since in some cases, at least, the percentage composition is approximately the same as that reported by these investigators. Our estimations compare very closely with those of Hopkins (*2, p. 75*) with the exceptions of the amounts of potassium and sulphur removed by the crop. The relatively large amount of potassium in the plants grown at Manhattan, Kans., was due probably to the fact that the soil in which the plants were grown was especially rich in this element, while the small amount of sulphur obtained by the earlier investigators was due to the naccuracy of the methods used in its estimation.

SUMMARY

An elemental analysis was made of five Pride of Saline corn plants grown in the field at Manhattan, Kans., in 1920. Determinations were made for carbon, oxygen, hydrogen, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, silicon, aluminum, chlorin and manganese.

In order to determine the variation in the composition of the different plants and their organs, separate analyses were made of the leaves, stem and grain of each of the five plants. A separate analysis was also made of each of five root systems of plants that were grown in soil in large metal containers.

The analytical results are tabulated and discussed in the text under the following headings:

Variations in the percentage and in the total weight of the elements that composed the various organs of the plants.

The percentage distribution of the different elements in the leaves, stems, grain, cobs, and roots of the plants.

The number of pounds of each of the elements removed per acre from the soil and air by a crop of corn.

LITERATURE CITED

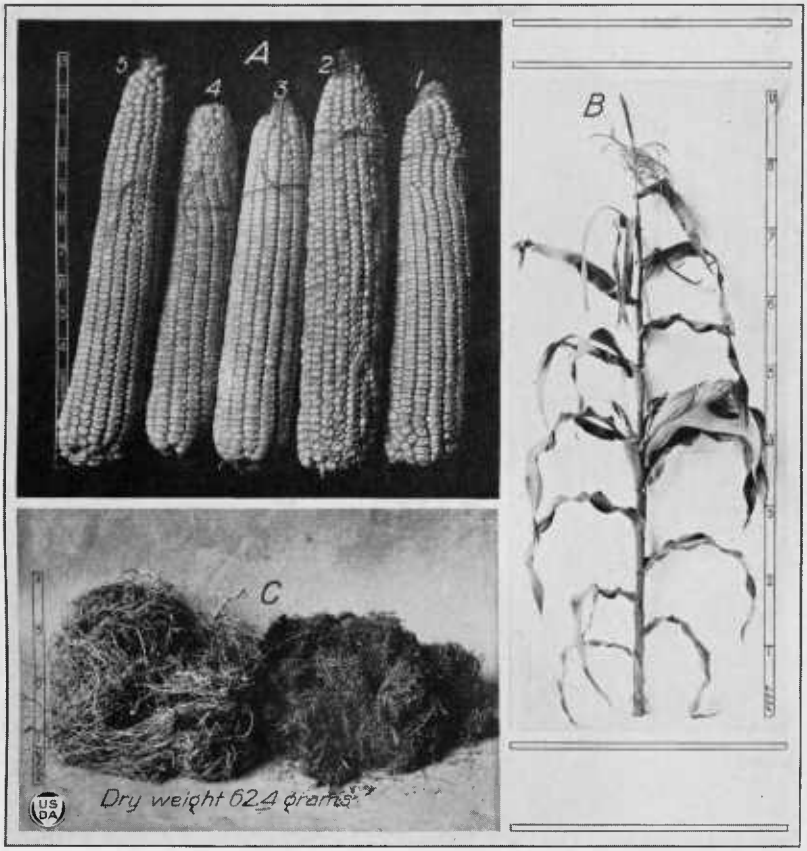
(1) DULEY, F. L., and MILLER, M. F.
1921. THE EFFECT OF A VARYING SUPPLY OF NUTRIENTS UPON THE CHARACTER AND COMPOSITION OF THE MAIZE PLANT AT DIFFERENT PERIODS OF GROWTH. Mo. Agr. Exp. Sta. Research Bul. 42, 66 p., 17 fig., 8 pl. Bibliography, p. 57–58.
(2) HOPKINS, C. G.
1910. SOIL FERTILITY AND PERMANENT AGRICULTURE. 653 p., illus. Boston, New York [etc.]
(3) HORNBERGER, R.
1882. CHEMISCHE UNTERSUCHUNGEN ÜBER DAS WACHSTHUM DER MAISPFLANZE. *In* Landw. Jahrb., Bd. 11, p. 359–523, illus.
(4) INCE, J. W.
1916. COMPOSITION OF THE MAIZE PLANT. N. Dak. Agr. Exp. Sta. Bul. 117, 32 p., 4 fig.
(5) JONES, W. J., and HUSTON, H. A.
1914. COMPOSITION OF MAIZE AT VARIOUS STAGES OF ITS GROWTH. Ind. Agr. Exp. Sta. Bul. 175, p. 599–630, illus.
(6) [LADD, E. F.]
1890. A STUDY OF THE MAIZE PLANT. N. Y. Geneva Agr. Exp. Sta. 8th Ann. Rpt., 1889, p. 79–91.
(7) LATSHAW, W. L.
1923. REPORT ON SULFUR AND PHOSPHORUS IN THE SEEDS OF PLANTS. *In* Jour. Assoc. Off. Agr. Chem. v. 6, p. 414–418.
(8) MILLER, E. C.
1916. RELATIVE WATER REQUIREMENT OF CORN AND THE SORGHUMS. *In* Jour. Agr. Research, v. 6, p. 473–484, 1 fig., pl. 70–72.
(9) ———
1923. RELATIVE WATER REQUIREMENT OF CORN AND SORGHUMS. Kans. Agr. Exp. Sta. Tech. Bul. 12, 34 p., 5 fig.
(10) SCHWEITZER, P.
1889. STUDY OF THE LIFE HISTORY OF CORN AT ITS DIFFERENT PERIODS OF GROWTH. Mo. Agr. Exp. Sta. Bul. 9, 78 p.
(11) SMITH, C. D.
1898. SOME EXPERIMENTS IN CORN RAISING. Mich. Agr. Exp. Sta. Bul. 154, p. 259–288.
(12) VIVIAN, Alfred.
1908. FIRST PRINCIPLES OF SOIL FERTILITY. 265 p., illus. New York.

PLATE 1

A.—Ears of the five Pride of Saline corn plants that were used for the elemental analyses.

B.—Pride of Saline corn plant No. 4 showing the general appearance of the five plants used for the elemental analyses.

C.—General appearance of one (B, Table IV) of the five root systems of Pride of Saline corn plants used in the chemical analyses.


A
5
4
3
2
1
B
C
Dry weight 62.4 grams
US DA